

Innovative Solutions for Waste Removal (Used Abrasive) Resulted from Water Jet Cutting Process

Ion-Aurel PERIANU^{1,a*}, Radu COJOCARU^{2,b}, Emilia-Florina BINCHICIU^{3,c},
Gabriela MNERIE^{4,d}

^{1,2,3,4}National Research & Development Institute for Welding and Material Testing – ISIM;
Address: 30, Mihai Viteazu Blvd., Postal Code 300222, Timisoara, Romania

^aaperianu@isim.ro, ^brcojocaru@isim.ro, ^cebinchiciu@isim.ro, ^dgmnerie@isim.ro

Keywords: waterjet, abrasive waste, disposal

Abstract. Due to the extraordinary qualities established and imposed worldwide, the water jet cutting process is increasingly used in current industrial applications.

It is well known that the process can be applied to a wide range of materials: metallic and non-metallic alloys, polymeric materials, ceramic materials, glass, stone, marble, wood, rubber, etc.

An important challenge in the conception and design of water jet cutting equipment is the removal of used abrasive material from the discharge tank during or after water jet cutting operations.

The paper presents innovative solutions proposed and developed worldwide for the evacuation / extraction from the tank of water jet cutting machines of used abrasive particles and / or particles resulting from materials subjected to the cutting process.

General Considerations

The water jet cutting process (figure 1) has demonstrated its special utility and efficiency by implementing for the processing of a wide range of materials.



Figure 1. Abrasive-water jet cutting process of a 10 mm steel plate on ISIM Timisoara equipment

The water jet cutting process consists in directing a high-pressure water jet (300 - 600 MPa) and high speed (500 - 900 m/s) to the cutting site. The high pressure of water jet exerts compressive stresses on the material, as a result of local shearing and erosion, the material is removed and the cutting angle is achieved. The cutting process causes a deformation of the cut surface, the angle of the striations (wrinkles) depends on the correlation between the cutting speed (translation of the part) and the power of the jet. As the cutting speed increases at a constant jet power (a constant water jet pressure and a constant abrasive flow) the inclination of the risers increases to the point of lack of penetration over the entire thickness of the material. The width of the cutting angle depends on the cutting variant

(without or with abrasive) being between $0.5 \div 2.5$ mm, the resulting surface roughness between $0.1 \div 0.6$ mm.

Advantages, with an emphasis on application possibilities:

- no heat is generated when cutting with a water jet - this is very important, especially when cutting materials where excessive heat could change the properties of the cut part;
- the joint resulting from the cutting has a small value and the material losses are small accordingly;
- it can be used to obtain prototype or unique parts. An operator can program the dimensions of the part, in the control station, and the equipment "cuts" the part according to the programming;
- It is less expensive and the necessary processing times are reduced compared to the usual procedures that involve making execution drawings for parts and then making parts by successive processing. [1]

Limitations as well as applicability / disadvantages:

- only certain categories of materials can be cut with economic advantages; although it is technically possible to cut tool steels and other hard materials, the cutting speed is significantly reduced, the time required to cut a single piece being quite long compared to cutting using other processes.
- because of the above mentioned disadvantage, cutting can have higher costs and the benefits do not compensate enough for the price of the operation;
- it is not possible to cut very thick parts without losing dimensional accuracy; if the piece is large, the water jet may dissipate, the cut may deviate diagonally, and the width of the resulting joint shall be greater at the bottom than at the top. [2]

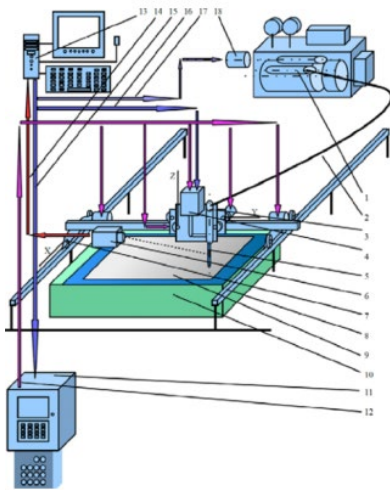
Considering special qualities, but also the economic impact through implementation in production activities, of approx. 12 years the water jet cutting process is part of the scientific program but also the industrial services program of ISIM Timisoara.

Water jet cutting equipment – general specification

The main components of a cutting machine are:

- hydraulic pump;
- water filtration system;
- hydraulic amplifier and accumulator;
- rigid and flexible connecting pipes;
- cutting head;
- abrasive supply system;
- part positioning system - cutting head;
- pressure relief and recovery unit;
- process control and command system. [3]

The schematic representation for a basic abrasive waterjet cutting unit is presented in Figure 2 A, respectively an abrasive waterjet cutting machine front view, property of ISIM Timisoara, is presented in Figure 2 B.



A - schematic representation of a water and abrasive jet cutting equipment



B - water and abrasive jet cutting equipment

Figure 2. ISIMs water and abrasive jet cutting equipment [3]

In the case of water jet and abrasive cutting, an important component of the machine with major effects on the efficiency of the process is the exhaust abrasive systems in the exhaust tank. These systems must ensure a minimal influence on the actual operating time of the machine.

Modern solutions of waste disposal (used abrasive) for water and abrasive jet cutting equipment

The material from the discharge tank resulted from a water jet and abrasive cutting process consists mainly of:

- used abrasives;
- residues from the material subjected to the cutting process;
- other small particles resulting from the operation of the equipment.

The way in which the used abrasive is evacuated and possibly recovered is very important from two points of view, namely:

- limiting to a minimum the non-use times in optimal conditions of the machine;
- the use of exhaust systems to allow the application of a technical solution for the easy separation of materials from the component of the abrasive material used (useful for example for cutting special metals / precious metals).

Water jet cutting equipment can be made in several variants of constructive solutions regarding the management of resulting particles during the water and abrasive jet cutting process.

In the following the authors present a series of waste removal or recovery systems that are currently used in the industrial sector, or/and are solutions provided by international scientists as patented solutions or patent request.

A. Abrasive removal system by directing the suspension of abrasive particles into a centrifugal filtration system. [4]

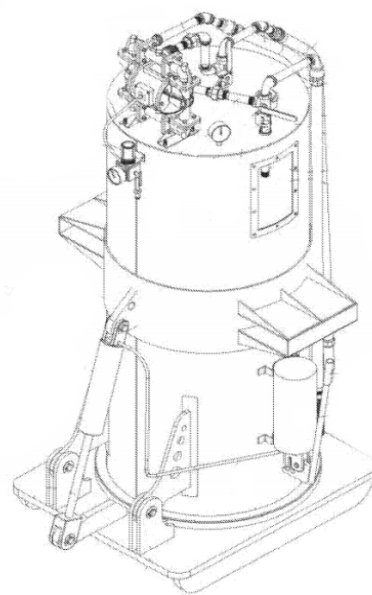
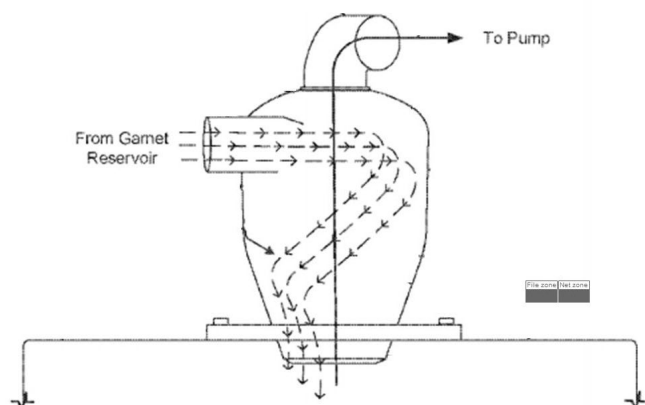


Figure 3. A. system for extracting particulate matter from a liquid body – centrifugal filtration system.

Figure 3. B. – perspective view of the system for extracting particulate matter from a body of liquid

Figure 3. Abrasive removal system [4]

The system shown in Figures 3 A + B, includes a cylindrical tank with a cavity, having an upper end and a lower end, a separator with transverse flow rigidly fixed to the upper end of the cylindrical tank, the fluid communicating with the empty cavity, an inlet pipe connected to the transverse flow separator, an outlet pipe connected to the transverse flow separator, a pump in communication with the outlet pipe and a fluid reservoir in fluid communication with the inlet. The method includes capturing particles and liquid in a tank, partially separating the particles and liquid in the tank, channeling the separated particles and liquid to a cross-flow separator positioned above the tank separating the partially separated particles and the liquid in the separator stream and capturing the particles in the tank.

The centrifugal filtration system separates the water particles by pumping the particle suspension through a centrifugal separator. A capture tank collects the used particles and the water separated from the abrasive particles can then be disposed of or recirculated to the capture tank to repeat the process of cleaning the abrasive particle suspension in the centrifugal filtration system.

B. Continuous abrasive cleaning system (GRS type), by means of automatic abrasive removal installations from the cutting machine tank. [5]



Figure 4. A. Garnet disposal system. [5]



Figure 4. B. Sanitary system for abrasive sweeping / removing installations. [5]



Figure 4. C. Abrasive removal / removal system. [5]

The Garnet Disposal System (GRS), shown in Figure 4 A, is designed to remove spent abrasive waste from the capture tank of a continuous water jet cutting equipment, thus eliminating downtime for cleaning, maximizing at the same time production.

System of sanitary sweeping / abrasive removal installations shown in figure 4 B - specially designed to fit dimensionally with the capture tank. The system of abrasive removal sanitary installations incorporates several educators / blowers, with a ratio of 4: 1. The educators intensify the water flow and keep the abrasive in suspension, pushing it towards the system with suction holes.

Abrasive removal / disposal system, shown in Figure 4 C - used abrasive waste is stored in a 1000 kg bag at the same speed as it enters the capture tank. Used abrasive waste is relatively clean and has no cutouts or pieces larger than 1/8 in diameter. The abrasive bag for used waste is easy to manage and is easily lifted from the disposal hopper with a fork after which it is disposed of.

C. Water jet and abrasive cutting equipment, with built-in abrasive tank assembly. [6]

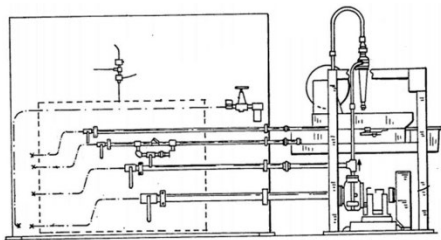


Figure 5. A. Front view of the water jet and abrasive cutting equipment incorporating the catchment tank assembly, including an enclosure where the abrasive water jet and the catchment tank assembly are located, including the recirculation system and filtration system; [6]

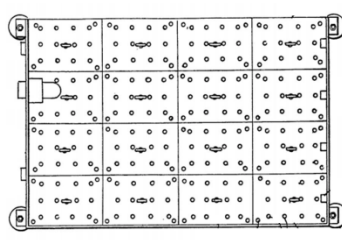


Figure 5. B. Overview of the capture tank; [6]

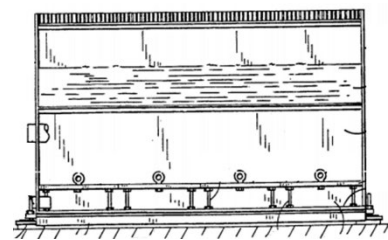


Figure 5. C. Abrasive removal / removal system. [6]

The system shown in Figure 5, A, B, C refers to a reservoir for capturing water jet and abrasive cutting equipment, which is equipped with a system that facilitates the recovery of used abrasive materials and metal residue resulting from the operation of a water jet and abrasive cutting equipment. The used material collection tank assembly includes a side and bottom clamping tank for collecting a fluid and includes a recirculation system for recirculating the fluid in the capture tank.

The spent material collection tank also includes connections to a filtration system for removing spent abrasive material and metal residue from the resulting fluid. The collection tank includes removable, consumable “wear-resistant support plates” that dissipate the residual energy resulting from the abrasive water jet, thus reducing damage to the tank. The wear plates are spaced above the bottom of the tank, thus dividing the tank into two compartments, an upper one that receives the abrasive water jet and a lower compartment, which is continuously washed, removing used abrasive materials and metal residues from the tank.

The recirculation system is designed to prevent the storage / agglomeration of used abrasive materials, scrap metal or other waste in the capture tank; including a general flow of water from the upper area to the lower area and also a scattered flow of water in the lower area. The liquid is discharged from the lower compartment in a drain through pipes leading to the filtration system. In the preferred version, the tank is portable and includes fork lift channels and quick disconnections that facilitate movement. The tank also includes leveling support legs as well as vibration isolation supports to reduce the vibration transmission to the module that generates the abrasive water jet from the water jet cutting equipment.

D) Waste abrasive drainage system with water recirculation. [7]

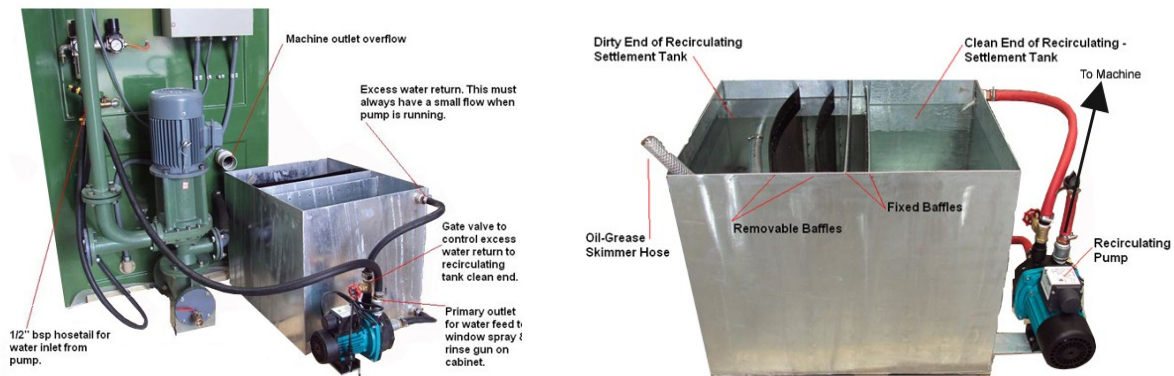


Figure 6. A. Front view of water jet and Figure 6. B. Front view of the capture tank; [7]
abrasive cutting equipment. [7]

The "dirty" end of the aluminum tank is positioned under the overflow of the machine. Sediments and oil / grease are trapped in the first compartments, while allowing relatively clean water to be recycled through the pump and attached hoses. Oil and grease can be decanted using the separator hose attached. It is then removed periodically, along with solids that have accumulated over time. The water and material suspension is recycled inside the appliance; Additional water is introduced into the pool during use. This extra water drains the spillway on the side or back of the car, taking with it used materials and oil / grease from parts.

The recirculation tank allows water to be recycled and eliminates the need to be attached to the water supply network. It also means that any chemical additives will not be diluted by use. That is, cost savings and an environmentally friendly configuration.

The recirculation tank offers the advantage of low water costs; and can create a complete closed loop system that can be positioned where water supply is not available. The only water loss is by evaporation.

E) Mobile waste disposal systems. [8]



Figure 7. Water recirculation system with tank [8]

Water recirculation system with 200L tank, recirculation pump with flow higher than 3LPM, filter at the pump outlet, adjustable bypass valve, two fixed deflectors attached to the bottom of the tank to form 2 dams over which water flows and two removable baffles attached to the top of the tank to force water to run under the baffles, widen the flow path and improve sedimentation of used material.

The unit has a stainless-steel tank and two 3 mm stainless steel deflectors. Also, in addition a stainless-steel lid with pipe-type legs, which fit on four positioning pins mounted in the upper corners of the tank. The pump requires a 240 V 10A single phase supply.

The pump unit is usually installed next to the grinder with a hose or water connection. Because the pump unit is on wheels, it can be rotated outwards for cleaning, etc. A sludge removal tool is provided.

A locking device is installed between the pump and the grinding motor so that the pump motor is stopped when the abrasive water jet activation motor is stopped.

F) Exhaust systems with vacuum pumps [9].

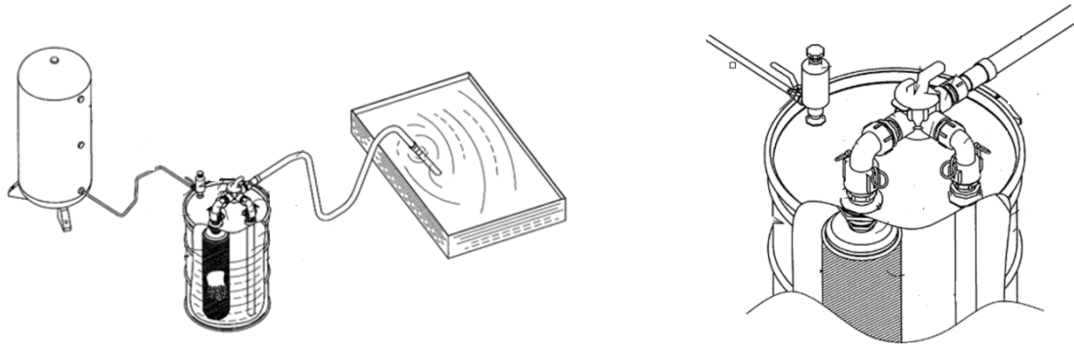


Figure 8. A. is a schematic perspective view of an embodiment of the disclosed liquid suction and filtration device, shown connected to a compressed air source and in which the interior of the container is partially broken to reveal the internal components; [9]

Figure 8. B. is a detail of the device in the adjacent figure, showing the tank lid and broken to show the inside of the container; [9]

Suction devices have been developed in a variety of models, each to perform a specific task or set of tasks. A common configuration of a suction device is a portable vacuum in which a container, which may be a drum or other closed container, is used to collect the material to be sucked. A flexible hose that ends in a rigid rod or other instrument is connected to the canister, and the rod is placed in or near the material to be collected. Such devices typically include a vacuum pump that lowers the pressure in the sealed container below ambient level, and the pressure difference causes the material to be sucked through the collection hose and collected inside the container. Such portable devices can be used for vacuuming and collecting dry, fluid particles or a combination of particular fluids and materials.

Certain types of suction devices may be adjusted to a suction configuration, in which the particulate material, a fluid or a combination thereof, is drawn through the collection hose and retained in the container, or to a discharge configuration, in which the operation of the vacuum pump is reversed to pressurize the inside of the container over ambient pressure. The pressurized interior forces the collected material, usually a fluid, to pass through the collection hose or, in some embodiments, through a second hose, thus emptying the contents of the container.

The liquid suction and filtration device may include a sealed container, a reversible vacuum pump that communicates with the inside of the container, a two-way valve mounted on the container, a flexible hose connected to the valve, a filter positioned inside the container and connected to valve and a stand pipe connected to the valve and extending inside the container. In one aspect, the vacuum pump may be a reversible pneumatic pump. When the reversible air pump and valve are adjusted to a filling configuration and the flexible hose is placed in or in a fluid containing particulate material, the pump discharges air from inside the container to create ambient pressure inside the container. This partial vacuum can cause the fluid to be sucked through the flexible hose, the valve and the filter inside the container. The inside of the container is filled with fluid and the filter can catch and collect the particulate material which has been suspended in the fluid or introduced through the hose together with the fluid.

The described reversible vacuum pump and valve can be adjusted to a discharge configuration in which the reversible vacuum pump pressurizes the inside of the container to a pressure above ambient

temperature. In this configuration, the valve can be adjusted to create a fluid flow channel through the pipe inside the container, through the valve and through the flexible hose. The above ambient pressure inside the container can cause the fluid inside to flow through this channel and be discharged through the hose.

ISIM proposed technical solution for abrasive waste disposal

The proposed solution takes into account the need to periodically displace the used abrasive so that it does not clog. Thus, the work tank is equipped with a number of parts through which pressurized water is drained into the tank, thus activating all the existing water mass together with the sand (used abrasive) obtained from the cutting processing. It is a water circuit connected to a power pump that ensures the required flow. This pipe is provided with a number of connecting elements, equipped with nozzles through which the pressurized water flows which will be discharged into the tank through the holes on the surface of the tank, resulting in controlled agitation of the mixture created, respectively water and abrasive.

This mixture will be discharged through a number of holes drilled in the bottom of the tank, on its horizontal surface.

Figure 9 A shows a drawing for the real-time evacuation system of used abrasive material, implemented in a water jet and abrasive cutting machine, in portal construction with two longitudinal guideways and a beam with transverse trolley, for performing combined cutting movements.

Figure 9 B schematically shows the location of the water agitation / homogenization system (by means of a pressurized water circuit) and used abrasive, in the working tank of a water jet and abrasive cutting installation.

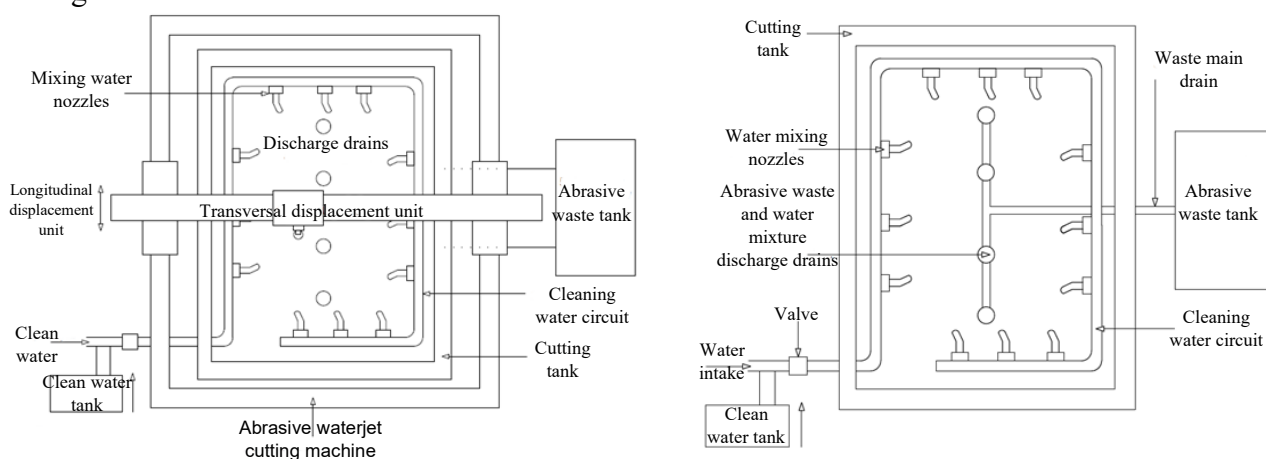


Figure 9 A Schematic for the real-time evacuation system of used abrasive material

Figure 9 B Waste abrasive cleaning solution principle

Conclusions

Water and abrasive jet cutting processes are important technological processes for industrial processing. These are rather new but mature processes with possibilities for expansion, as information of technological nature regarding different cutting applications and different materials to be processed are developed. It is a current process with extraordinary qualities and versatility in application.

By implementing into production an abrasive removal system we can achieve the following benefits:

- Maximizes productivity - eliminating the time required to clean the capture tank;
- Reduces the possibility of thermal distortion - by removing the abrasive from the table, the heat resulting from the machining process is dissipated;
- Reduces consumable costs in a closed loop system - by removing abrasive from wastewater, the filtration system can maximize water treatment rather than removing abrasive;

➤ Abrasive sweepers are part of the removal system and are designed to prevent abrasive from dispersing into all areas of the capture tank.

By mounting a recirculation tank on an industrial water and abrasive jet cutting equipment the following advantages can be obtained:

- Makes the system completely "closed" and able to operate in industrial conditions and with minimum down times;
- Environmentally friendly, minimizes waste production and reduces waste disposal indirect costs;
- Filters oil / grease for easy settling and disposal;
- Detachable baffles for easy cleaning;
- Stores and filters "used abrasive" and prepares it for disposal;
- Allows water to be recycled back into the machine, which means there is no water loss;
- No dilution of chemical additives inside the machine, which leads to savings in casting.

A very important aspect for the efficiency of the process is the continuity of the effective cutting time. From this point of view, a factor with major influence is the way in which management of the used abrasive is solved; presented solutions can be applied to this end.

References

- [1] Jayakrishna Kandasamy, (2017), Sustainability studies on abrasive water jet cutting process, International Conference on Waste Management - RECYCLE 2016, At: IIT Guwahati;
- [2] Ludmila Volgina, Stanislav Sergeev, (2020), Water jet cutting resistance, IOP Conference Series Materials Science and Engineering, Volume 869, NEW CONSTRUCTION TECHNOLOGIES, July 2020, doi:10.1088/1757-899X/869/7/072035.
- [3] I.A. Perianu, D. Ionescu, V. Verbițchi, "Method of measuring the abrasive-water jet diameter, for cutting process control", Welding and Material Testing – BID, no.1/2017.
- [4] <https://patentimages.storage.googleapis.com/30/33/a3/4091ce565f8baf/WO2015176688A1.pdf>
- [5] <https://akscutting.com/wp-content/uploads/2018/12/AKS-GRS-brochure-11-18.pdf>
- [6] <https://patentimages.storage.googleapis.com/a9/26/3e/e82708cee9b412/US5127199.pdf>
- [7] <https://dana-ridge.com.au/recirculating-tank/>
- [8] <http://www.hylecontrols.com.au/wp-content/uploads/2012/03/Water-Recirculation-Tank-for-Marui-Grinder.pdf>
- [9] http://abpat.kipris.or.kr/abpat/remoteFile.do?method=fullText&publ_key=US000008153001B2&cntry=US&patno_fg=PAN